CLAIMS

I CLAIM:

1. A position sensing system, comprising:

a variable frequency signal source coupled to receive a frequency control signal and operable, in response thereto, to supply a sensor drive signal at a frequnecy;

a transmission line sensor having one or more resonant frequencies, the transmission line sensor including a sensor conductor and a moveable dielectric at least partially surrounding the sensor conductor, the sensor conductor having a driven end coupled to receive the sensor drive signal and a terminal end configured to reflect the sensor drive signal to thereby supply a reflected signal to the driven end, the moveable dielectric configured to receive a drive force and, upon receipt thereof, to move the dielectric to a position and thereby vary the one or more resonant frequencies of the transmission sensor;

a summing circuit coupled to receive the sensor drive signal and the reflected signal and operable, in response thereto, to supply a standing wave signal having an amplitude that varies with the one or more resonant frequencies of the transmission line sensor;

a control circuit coupled to receive the standing wave signal and operable, in response thereto, to (i) determine the sensor drive signal frequency relative to at least one of the transmission line sensor resonant frequencies and (ii) supply the frequency control signal to the variable frequency source, to thereby adjust the sensor drive signal frequency to substantially match at least one of the transmission line sensor resonant frequencies; and

a position determination circuit coupled to receive the adjusted sensor drive signal and operable, in response thereto, to determine the position of the moveable dielectric relative to the sensor conductor.

2. The system of Claim 1, wherein the variable frequency signal source comprises a voltage controlled oscillator circuit.

3. The system of Claim 1, wherein the control circuit comprises a lock-in amplifier circuit.

4. The system of Claim 1, wherein the control circuit determines the sensor drive signal frequency relative to at least one of the transmission line sensor resonant frequencies by determining a derivative of the standing wave signal amplitude with respect to the sensor drive signal frequency.

5. The system of Claim 1, further comprising:

a fixed-frequency signal source operable to supply a fixed-frequency modulation signal,

wherein the variable frequency source is further coupled to receive the fixed-frequency modulation signal and is further operable, in response thereto, to frequency modulate the sensor drive signal based on the fixed-frequency modulation signal.

6. The system of Claim 1, wherein the resonant transmission line sensor is configured as an embedded stripline resonant transmission line.

7. The system of Claim 1, wherein the summing circuit comprises:

a first resistor coupled between the sensor conductor and the variable frequency signal source;

a second resistor coupled between the sensor conductor and the control circuit; and

a third resistor coupled between the sensor conductor and a circuit common.

8. The system of Claim 1, wherein the position determination circuit comprises:

a frequency to voltage converter circuit coupled to receive the adjusted sensor drive signal and operable, in response thereto, to supply a DC signal having a voltage magnitude proportional to the position of the moveable dielectric.

9. The system of Claim 1, wherein the resonant transmission line sensor comprises:

first and second conductive substrates; and

a fixed dielectric substrate having at least a first surface and a second surface, the sensor conductor coupled to at least one of the first and second surfaces,

wherein the moveable dielectric includes:

a first moveable dielectric substrate disposed between the first conductive substrate and the fixed dielectric substrate first surface,

a second moveable dielectric substrate disposed between the second conductive substrate and the fixed dielectric substrate second surface.

10. The system of Claim 9, further comprising:

a dielectric coating covering at least a portion of the fixed dielectric substrate and at least a portion of the sensor conductor.

11. The system of Claim 9, further comprising:

a dielectric coating covering at least portions of the fixed dielectric substrate, the sensor conductor, the first moveable dielectric substrate, and the second dielectric substrate.

12. The system of Claim 9, wherein each of the substrates comprises alumina.

13. The system of Claim 1, wherein the position determination circuit is further operable to supply a signal representative of the position of the moveable dielectric relative to the sensor conductor, and wherein the system further comprises:

a reference variable frequency signal source coupled to receive a reference frequency control signal and operable, in response thereto, to supply a reference sensor drive signal;

a reference transmission line sensor having one or more resonant frequencies, the reference transmission line sensor including a reference conductor and the moveable dielectric at least partially surrounding the reference conductor, the reference conductor having a driven end coupled to receive the reference sensor drive signal and a terminal end configured to reflect the reference sensor drive signal to thereby supply a reference reflected signal to the driven end, the moveable dielectric configured, upon receipt of the drive force, to move to a position and thereby vary the one or more resonant frequencies of the reference transmission sensor;

a reference summing circuit coupled to receive the reference sensor drive signal and the reference reflected signal and operable, in response thereto, to supply a reference standing wave signal having an amplitude that varies with the one or more resonant frequencies of the reference transmission line sensor;

a reference control circuit coupled to receive the reference standing wave signal and operable, in response thereto, to (i) determine the reference sensor drive signal frequency relative to at least one of the reference transmission line sensor resonant frequencies and (ii) supply the reference frequency control signal to the reference variable frequency source, to thereby adjust the reference sensor drive signal frequency to substantially match at least one of the reference transmission line sensor resonant frequencies;

a reference position determination circuit coupled to receive the adjusted reference sensor drive signal and operable, in response thereto, to determine the position of the moveable dielectric relative to the reference conductor and supply a signal representative thereof; and

a temperature compensation circuit coupled to receive the signal representative of the position of the moveable dielectric relative to the sensor conductor and the signal representative of the moveable dielectric relative to the reference conductor and operable, in response thereto, to supply a temperature compensated position signal representative of the position of the moveable dielectric relative to the sensor conductor.

14. The system of Claim 13, wherein the temperature compensation circuit comprises:

a difference amplifier coupled to receive the signal representative of the position of the moveable dielectric relative to the sensor conductor and the signal representative of the moveable dielectric relative to the reference conductor and operable, in response thereto, to supply a signal representative of a difference thereof as the temperature compensated position signal.

15. The system of Claim 13, wherein the temperature compensation circuit is further operable, in response to receipt of the signal representative of the position of the moveable dielectric relative to the sensor conductor and the signal representative of the moveable dielectric relative to the reference conductor, to determine a temperature of at least the sensor conductor.

16. The system of Claim 15, wherein the temperature compensation circuit comprises:

a summing amplifier coupled to receive the signal representative of the position of the moveable dielectric relative to the sensor conductor and the signal

representative of the moveable dielectric relative to the reference conductor and operable, in response thereto, to supply a signal representative of a sum thereof,

wherein the sum signal is representative of the temperature of at least the sensor conductor.

17. A position determination system, comprising:

a sensor variable frequency signal source and a reference variable frequency signal source, the sensor and reference variable frequency signal sources coupled to receive a sensor and a reference frequency control signal, respectively, and operable, in response thereto, to supply a sensor and a reference drive signal, respectively, at a frequency;

a differential transmission line sensor having one or more sensor resonant frequencies and one or more reference resonant frequencies, the differential transmission line sensor including a sensor conductor, a reference conductor, and a moveable dielectric at least partially surrounding the sensor and reference conductors, the sensor and reference conductors each having a driven end coupled to receive the sensor and reference drive signals, respectively, and a terminal end configured to reflect the sensor and reference drive signals, respectively, to thereby supply a reflected sensor signal and a reflected reference signal to the sensor and reference driven ends, respectively, the moveable dielectric configured to receive a drive force and, upon receipt thereof, to move the dielectric to a position and thereby vary the one or more sensor and reference resonant frequencies of the differential transmission line sensor;

a sensor summing circuit and a reference summing circuit, the sensor and reference summing circuits coupled to receive the sensor drive and sensor reflected signals and reference drive and reference reflected signals, respectively, and operable, in response thereto, to supply a sensor standing wave signal and a reference standing wave signal, each standing wave signal having an amplitude that varies with the one or more sensor resonant frequencies and the one or more reference resonant frequencies of the differential transmission line sensor, respectively;

a sensor and a reference control circuit, the sensor and reference control circuits coupled to receive the sensor and reference standing wave signals, respectively, and operable, in response thereto, to (i) determine the sensor and reference drive signal frequencies relative to at least one resonant frequency of the

sensor and reference transmission line sensors, respectively, and (ii) supply the sensor and reference frequency control signals to the sensor and reference variable frequency sources, respectively, to thereby adjust the sensor and reference drive signal frequencies to substantially match at least one sensor and at least one reference resonant frequency, respectively, of the differential transmission line sensor;

a sensor and a reference relative position determination circuit, the sensor and reference position determination circuits each coupled to receive the adjusted sensor and reference drive signals, respectively, and operable, in response thereto, to supply a sensor and reference relative position signal, respectively, representative of moveable dielectric position relative to the sensor and reference conductor, respectively; and

a position signal generation circuit coupled to receive the sensor and reference relative position signals and operable, in response thereto, to supply a temperature compensated position signal representative of the position of the moveable dielectric relative to the sensor conductor.

18. The system of Claim 17, further comprising:

a temperature signal generation circuit coupled to receive the sensor and reference relative position signals and operable, in response thereto, to supply a temperature signal representative of a temperature of the differential transmission line sensor.

19. A system for measuring temperature, comprising:

a sensor variable frequency signal source and a reference variable frequency signal source, the sensor and reference variable frequency signal sources coupled to receive a sensor and a reference frequency control signal, respectively, and operable, in response thereto, to supply a sensor and a reference drive signal, respectively, at a frequency;

a differential transmission line sensor having one or more sensor resonant frequencies and one or more reference resonant frequencies, the differential transmission line sensor including a sensor conductor, a reference conductor, and a moveable dielectric at least partially surrounding the sensor and reference conductors, the sensor and reference conductors each having a driven end coupled to receive the sensor and reference drive signals, respectively, and a terminal end configured to reflect the sensor and reference drive signals, respectively, to thereby supply a reflected sensor signal and a reflected reference signal to the sensor and reference driven ends, respectively, the moveable dielectric configured to receive a drive force and, upon receipt thereof, to move the dielectric to a position and thereby vary the one or more sensor and reference resonant frequencies of the differential transmission line sensor;

a sensor summing circuit and a reference summing circuit, the sensor and reference summing circuits coupled to receive the sensor drive and sensor reflected signals and reference drive and reference reflected signals, respectively, and operable, in response thereto, to supply a sensor standing wave signal and a reference standing wave signal, each standing wave signal having an amplitude that varies with the one or more sensor resonant frequencies and the one or more reference resonant frequencies of the differential transmission line sensor, respectively;

a sensor and a reference control circuit, the sensor and reference control circuits coupled to receive the sensor and reference standing wave signals, respectively, and operable, in response thereto, to (i) determine the sensor and reference drive signal frequencies relative to at least one resonant frequency of the

sensor and reference transmission line sensors, respectively, and (ii) supply the sensor and reference frequency control signals to the sensor and reference variable frequency sources, respectively, to thereby adjust the sensor and reference drive signal frequencies to substantially match at least one sensor and at least one reference resonant frequency, respectively, of the differential transmission line sensor;

a sensor and a reference relative position determination circuit, the sensor and reference position determination circuits each coupled to receive the adjusted sensor and reference drive signals, respectively, and operable, in response thereto, to supply a sensor and reference relative position signal, respectively, representative of moveable dielectric position relative to the sensor and reference conductor, respectively; and

a position signal generation circuit coupled to receive the sensor and reference relative position signals and operable, in response thereto, to supply a temperature compensated position signal representative of the position of the moveable dielectric relative to the sensor conductor; and

a temperature signal generation circuit coupled to receive the sensor and reference relative position signals and operable, in response thereto, to supply a temperature signal representative of a temperature of the differential transmission line sensor.

20. A resonant transmission line sensor, comprising:

a first conductive substrate;

a second conductive substrate;

a sensor substrate having at least a first and second surface, the sensor substrate disposed between the first and second conductive substrates;

a sensor conductor coupled to the sensor substrate first surface; and

a movable dielectric disposed between the first conductive substrate and the sensor conductor, the moveable dielectric configured to receive a drive force and, upon receipt thereof, to move relative to the sensor conductor.

21. The sensor of Claim 20, wherein the sensor conductor is formed into a serpentine pattern on the sensor substrate first surface.

22. The sensor of Claim 20, further comprising:

a dielectric coating covering at least a portion of the sensor dielectric substrate and at least a portion of the sensor conductor.

23. The sensor of Claim 20, wherein the moveable dielectric comprises:

a first moveable dielectric substrate disposed between the first conductive substrate and the sensor conductor; and

a second moveable dielectric substrate coupled to the first moveable dielectric substrate and disposed between the second conductive substrate and the sensor substrate second surface.

24. The system of Claim 20, further comprising:

a dielectric coating covering at least portions of the sensor dielectric substrate, the sensor conductor, the first moveable dielectric substrate, and the second dielectric substrate.

25. The system of Claim 20, wherein the sensor substrate comprises a dielectric.

26. The system of Claim 25, wherein the dielectric comprises alumina.

27. The system of Claim 20, wherein the sensor conductor comprises silver.

28. A method of determining a position of moveable component, comprising the steps of:

moving a dielectric in response to movement of the moveable component, the dielectric disposed within a resonant transmission line adjacent a sensor conductor, whereby movement of the dielectric varies an impedance and a resonant frequency of the resonant transmission line;

supplying a sensor drive signal to the resonant transmission line conductor, to thereby produce a reflected signal, the sensor drive signal having a frequency;

summing the sensor drive signal and the reflected signal to produce a standing wave signal;

determining the sensor drive signal frequency relative to a resonant frequency of the transmission line;

adjusting the sensor drive signal frequency to substantially match a resonant frequency of the transmission line; and

determining the position of the moveable component based at least in part on the adjusted sensor drive signal frequency.

29. The method of Claim 28, wherein the reflected signal has at least an amplitude, and wherein the step of determining the sensor drive signal frequency relative to a resonant frequency of the transmission line comprises:

determining a first derivative of the reflected signal amplitude with respect to the sensor drive signal frequency.

30. The method of Claim 28, further comprising:

frequency modulating the sensor drive signal based on a modulation signal having a modulation frequency and phase;

detecting a phase of the reflected signal relative to the phase of the modulation signal; and

determining the sensor drive signal frequency relative to the resonant frequency of the transmission line based on the relative phases of the reflected signal and the modulation signal.

31. The method of Claim 28, wherein the resonant transmission line comprises a sensor section that includes the sensor conductor, and a reference section that includes a reference conductor, and wherein the method further comprises:

moving the dielectric, in response to the movement of the moveable component, relative to the reference conductor, whereby movement of the dielectric varies a resonant frequency of the resonant transmission line sensor and reference sections;

supplying a reference sensor drive signal to the reference conductor, to thereby produce a reference reflected signal, the reference sensor drive signal having a frequency;

summing the reference sensor drive signal and the reference reflected signal to produce a reference standing wave signal;

determining the reference sensor drive signal frequency relative to a resonant frequency of the resonant transmission line reference section;

adjusting the reference sensor drive signal frequency to substantially match a resonant frequency of the resonant transmission line reference section; and

determining the position of the moveable component based at least in part on the adjusted sensor drive signal frequency and the adjusted reference sensor drive signal frequency.

32. A method of making a resonant transmission line sensor, comprising:

forming a pattern onto a surface of a fixed dielectric substrate, the pattern having a first end and a second end and at least one slot formed therein that extends at least partially between the pattern first and second ends;

inserting a conductor into the at least one slot formed in the pattern;

disposing the fixed dielectric substrate between first and second conductive substrates, the fixed dielectric substrate spaced apart from at least the first conductive substrate to form a space therebetween; and

disposing a moveable dielectric substrate into the space formed between the fixed dielectric substrate and the first conductive substrate.